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Great Lakes
Water Quality
Surveys Program

[redacted]

NEARSHORE UNDER ICE
WATER MOVEMENT AT
NANTICOKE, LAKE ERIE
1970

135 St. Clair Ave. West,
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May 1970

NEARSHORE UNDER ICE WATER MOVEMENT AT NANTICOKE, LAKE ERIE

1970

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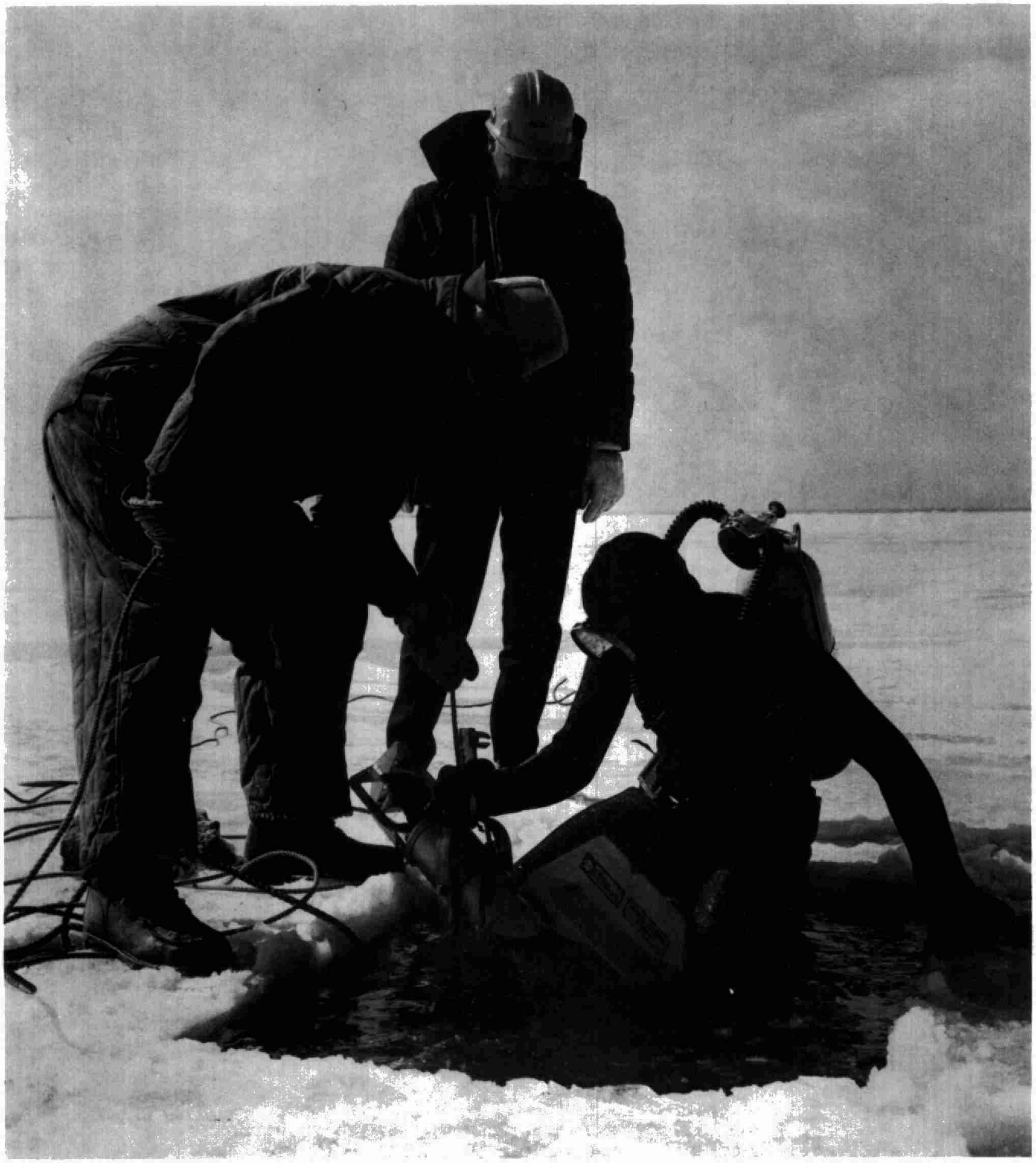


SERVICING CURRENT METER

NEARSHORE UNDER ICE WATER MOVEMENT AT NANTICOKE, LAKE ERIE 1970

ABSTRACT

Currents were measured at Nanticoke, Lake Erie, with a recording current meter from December 1969 to March 1970, when an ice cover existed in the area. The currents were measured at a fixed point 700 m from the shore at a point 3 m from the bottom in 11 m of water. The water movements were generally in the same direction as those without an ice cover; however, longer periods of little or no water movement existed. Periods of velocity jetting occurred after the ice cover formed. The mean monthly and hourly dispersion characteristics with an ice cover were significantly less than without an ice cover, particularly in February, indicating the need to avoid waste discharges in the adjacent nearshore areas.

NEARSHORE UNDER ICE WATER MOVEMENT AT NANTICOKE, LAKE ERIE 1970

INTRODUCTION

A recording current meter was operated under the winter ice at the 8 m depth location 021 (See Figure 1) from December 1969 to March 1970. The meter was serviced by divers operating through holes cut through the 30 cm thick ice. Extensive water movement studies had been conducted in this area during the ice free months of April to December in 1968 and 1969, but no surveys were conducted during ice conditions. This study was undertaken to determine water movement characteristics with an ice cover in the area of the proposed cooling water intake for the Nanticoke thermal generating station. The cooling water intake is to be used as the water intake for a regional water supply scheme. It is important to define the water movements in the adjacent area of the intake during ice conditions to ensure that the water quality in the area is maintained by existing movements during winter ice.

RESULTS

A Plessey Model M0.21 current meter was operated on a fixed underwater tower at location 021 (See Figure 1) at 3 m from the

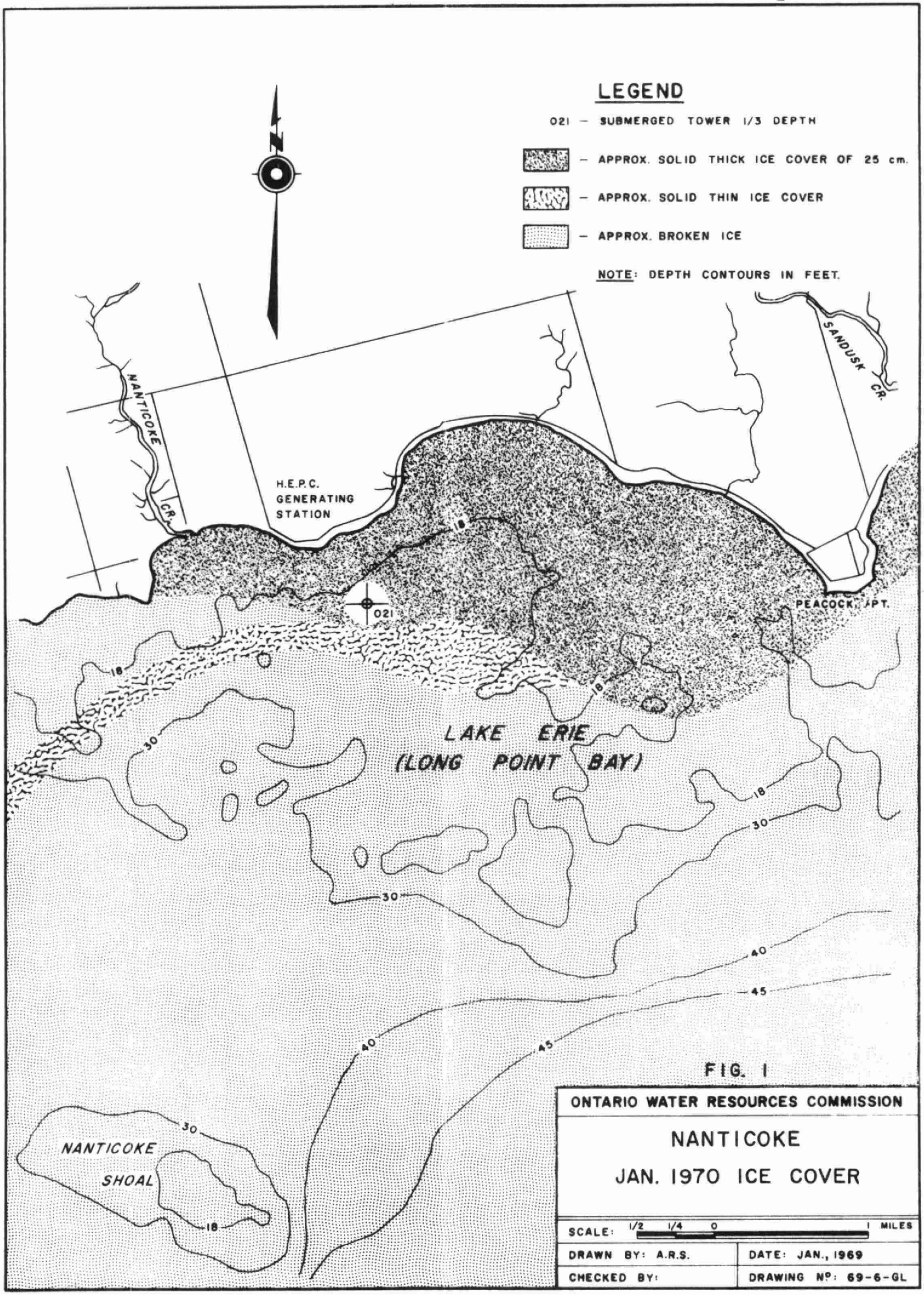


FIG. 1

ONTARIO WATER RESOURCES COMMISSION

NANTICOKE

JAN. 1970 ICE COVER

SCALE: 1/2 1/4 0 1 MILES

DRAWN BY: A.R.S. | DATE: JAN., 1969

CHECKED BY: | DRAWING Nº: 69-6-GL

bottom in 11 m of water (for details of the structure see Palmer (1968). The meter was set to record current magnitude, direction and temperature every ten minutes. A summary of the results appears in Table 1 with detailed tabulation appearing in Appendix 1. October 1968 and May 1969 results also appear in Table 1 for comparison to typically representative months from other studies. The records are not continuous as the meter battery failed under the severe winter operating conditions between January 27 and February 19.

TABLE 1

SUMMARY

	Dec. 22, 1969 Jan. 27, 1970	Feb. 19 to Mar. 11, 1970	Oct. 1968	May 1969
Maximum Velocity cm/sec	28.2	15.0	24.6	32.4
Period of zero velocity (percent of recording period)	40%	74%	19%	33%
Velocity cm/sec exceeded 5% of period	14.9	9.3	15	13.7
Resultant velocity cm/sec - directions coming from	2.16 at 255°	1.5 at 69°	1.5 at 272	2.43 at 256
Persistence	0.56	0.61	0.29	0.66

A log of the operation of the meter appears in Appendix 2. The practice of insitu calibrations of the meters with drogue trackings could obviously not be carried out under ice conditions. However, the meters were calibrated in the tow tank of the Hydro Electric Power Commission's hydraulic models laboratory after removal. The tow tank calibrations are presented in Appendix 3. The meter was found to be functioning properly and the results are considered valid.

It is practice to compare currents with winds and water levels, however, these data were not available. An autospectral analysis of both currents and temperatures revealed no significant peaking at any period although a minor peak occurred at 9.4 hours in east component of currents and temperature.

The monthly and hourly dispersion characteristics for continuous point source for the measured currents were computed employing the methods developed in "Great Lakes Nearshore Modelling from Current Meter Data, 1969" (Palmer, 1969). Monthly plumes were not developed for calendar months but for two periods of three and four weeks each, because of the above mentioned battery failure. The monthly concentration contours appear in Figures 2 and 3 and the hourly dispersion characteristics are presented in Figures 4 and 5, with a summary of five hour dispersion characteristics in Tabel 2.

TABLE 2

TWO DIMENSIONAL FIVE HOUR DISPERSION CHARACTERISTICS

		SOUTH	NORTH	EAST	WEST
Dec. 22 - Jan. 27, 1970					
$\sqrt{\overline{y^2}}$	cm (spread)	8.31×10^4	8.57×10^4	13.2×10^4	12.6×10^4
ϵ	cm^2/sec	1.92×10^5	2.04×10^5	4.82×10^5	4.38×10^5
$\overline{U}$	cm/sec	4.13	2.52	8.30	7.00
Probability		0.16	0.35	0.24	0.25
Feb. 19 - Mar. 11, 1970					
$\sqrt{\overline{y^2}}$	cm	0	5.47×10^4	6.80×10^4	6.54×10^4
ϵ	cm^2/sec	0	0.834×10^5	1.29×10^5	1.19×10^5
$\overline{U}$	cm/sec	0	2.22	4.25	4.43
Probability		0	0.52	0.134	0.34

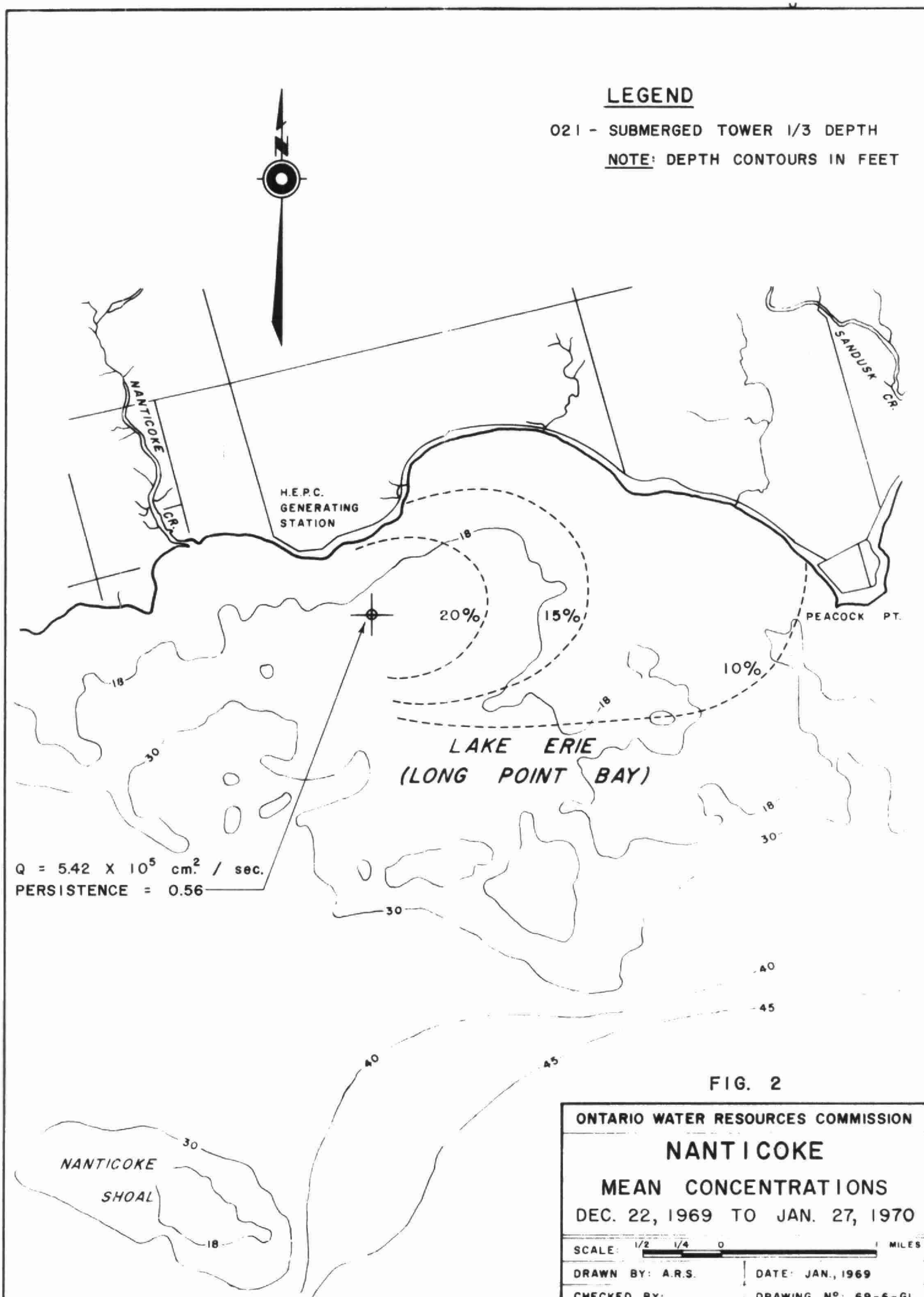


FIG. 2

ONTARIO WATER RESOURCES COMMISSION

NANTICOKE

MEAN CONCENTRATIONS

DEC. 22, 1969 TO JAN. 27, 1970

SCALE: 1/2 1/4 0 1 MILES

DRAWN BY: A.R.S. DATE: JAN., 1969

CHECKED BY: DRAWING N°: 69-6-GL

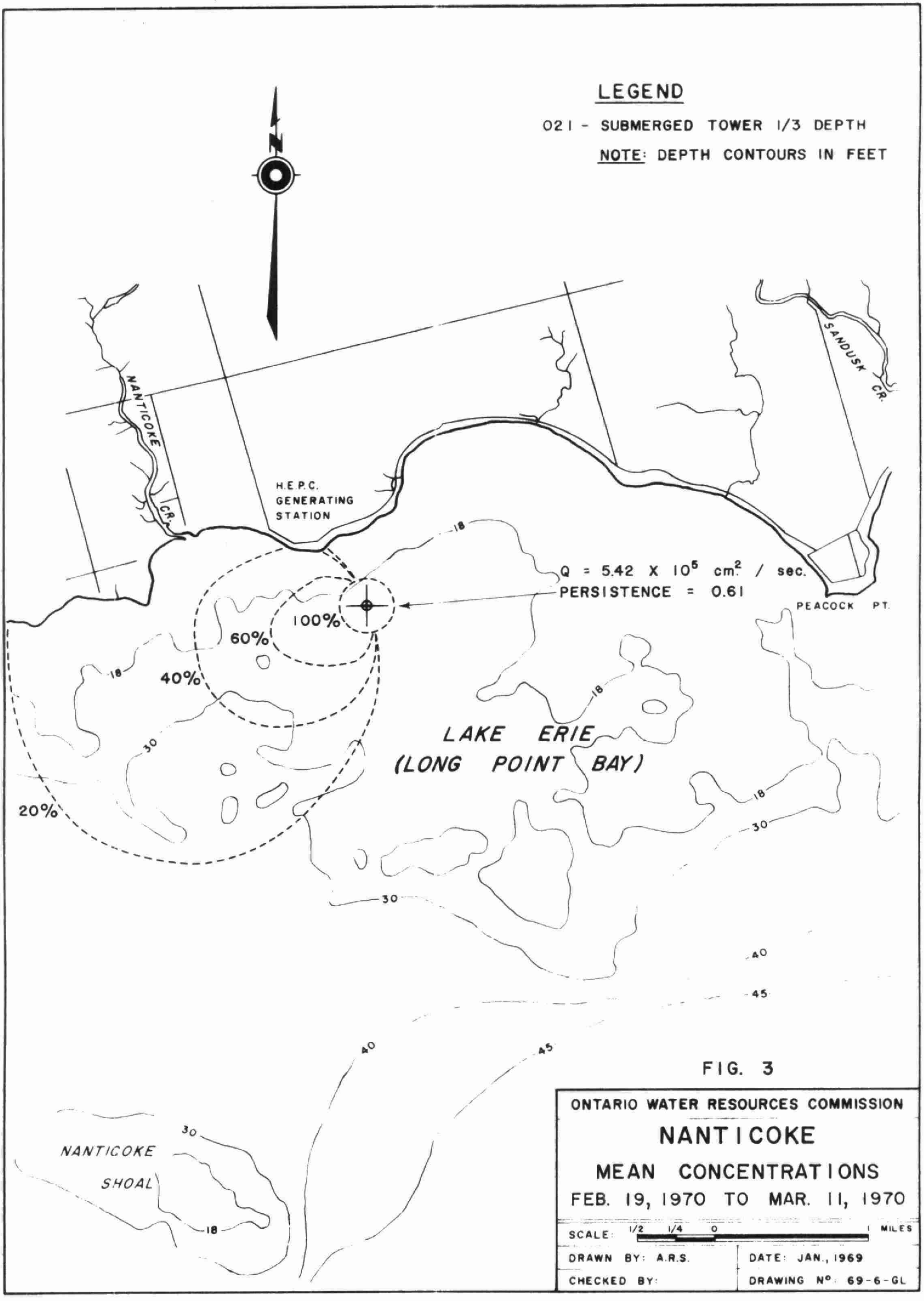


FIG. 3

ONTARIO WATER RESOURCES COMMISSION

NANTICOKE

MEAN CONCENTRATIONS

FEB. 19, 1970 TO MAR. 11, 1970

SCALE: 1/2 1/4 0 1 MILES

DRAWN BY: A.R.S.	DATE: JAN., 1969
CHECKED BY:	DRAWING Nº: 69-6-GL

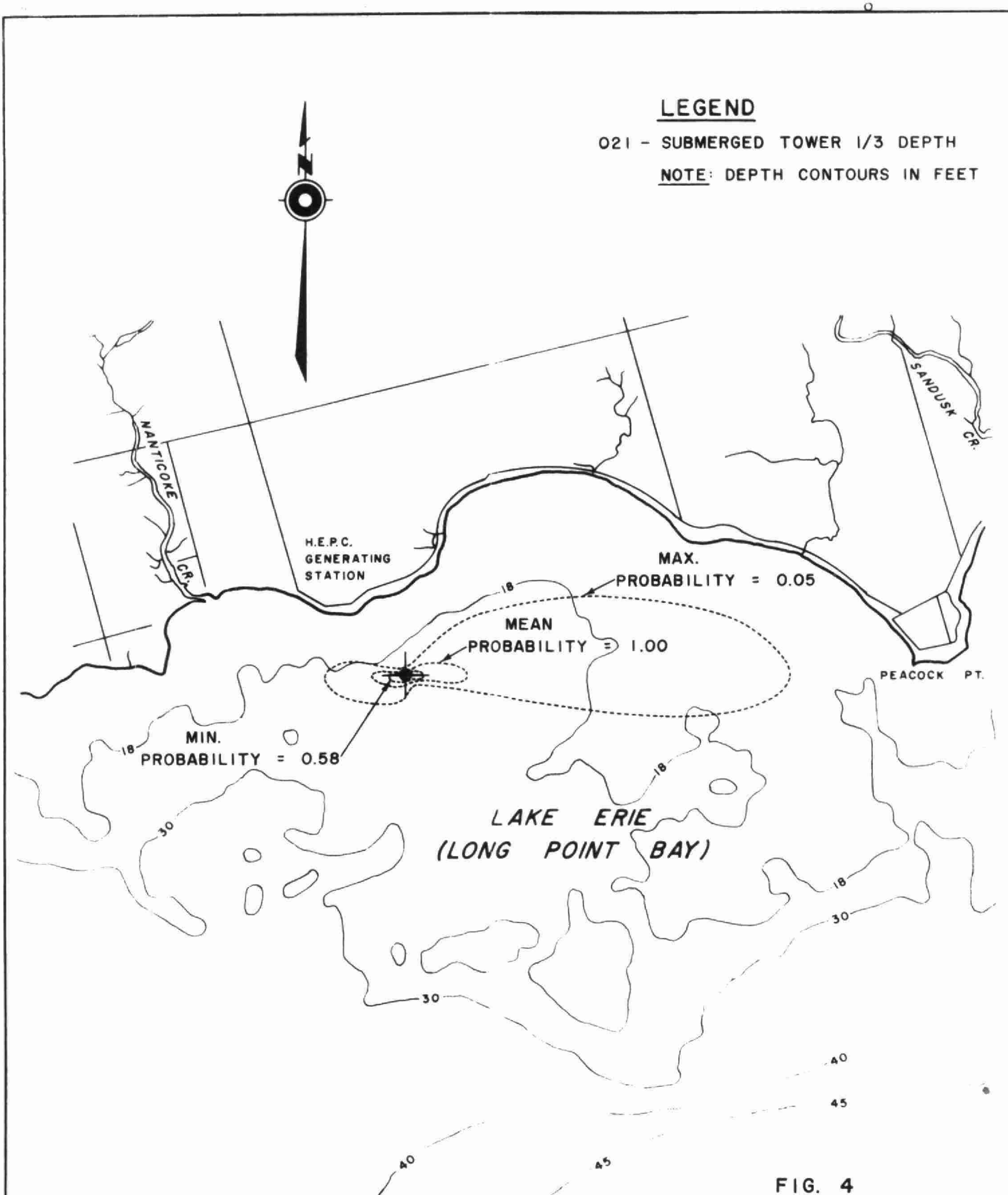


FIG. 4

ONTARIO WATER RESOURCES COMMISSION

NANTICOKE

EIGHT HOUR DISPERSION

DEC. 22, 1969 TO JAN. 27, 1970

DRAWN BY: A.R.S.	DATE: JAN., 1969
CHECKED BY:	DRAWING Nº: 69-6-GL

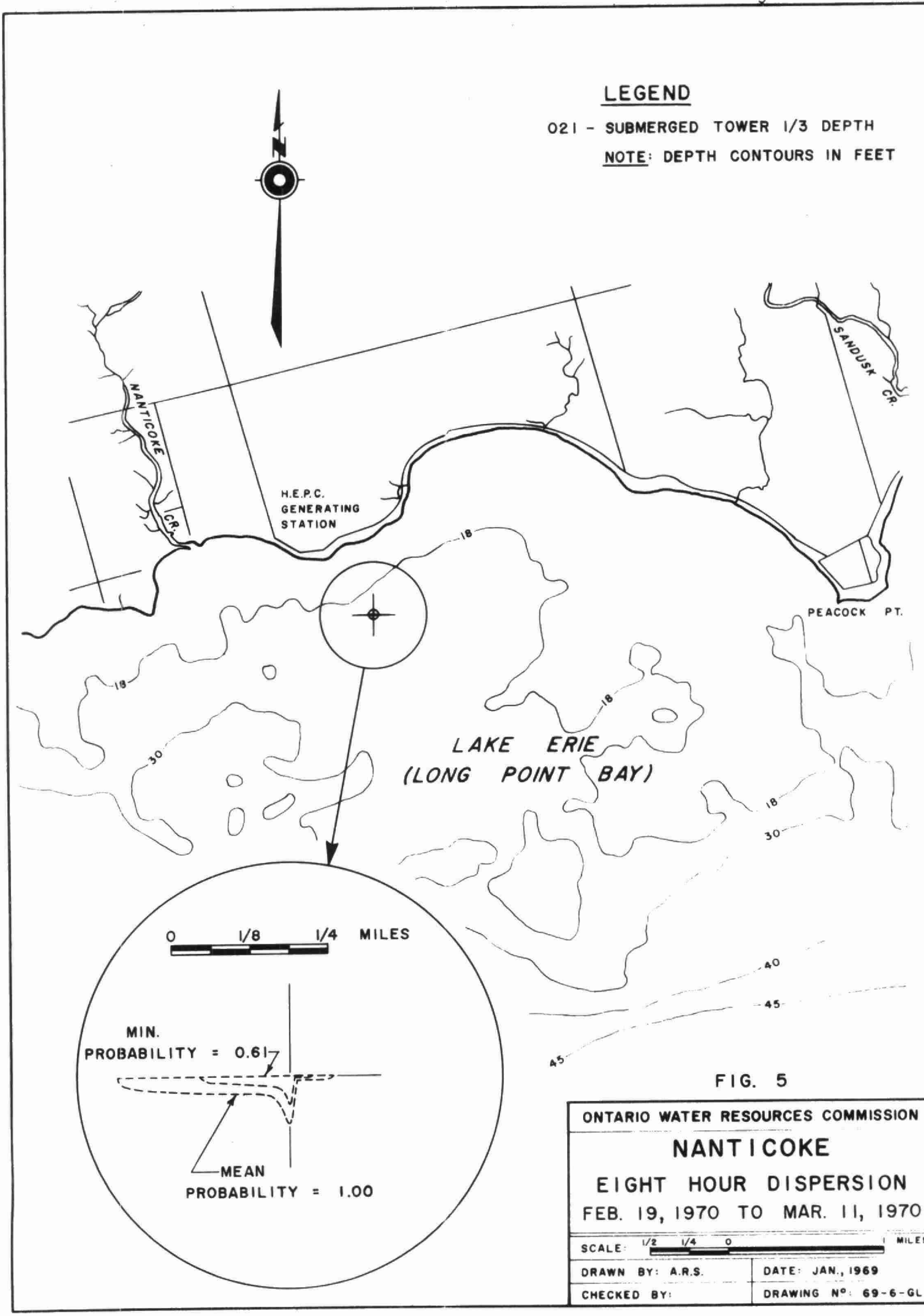

LEGEND
021 - SUBMERGED TOWER 1/3 DEPTH
NOTE: DEPTH CONTOURS IN FEET
NANTICOKE CR.
H.E.P.C. GENERATING STATION
SANDUSK CR.
PEACOCK PT.
LAKE ERIE (LONG POINT BAY)
18
30
40
45
0 1/8 1/4 MILES
MIN. PROBABILITY = 0.61
MEAN PROBABILITY = 1.00
ONTARIO WATER RESOURCES COMMISSION
NANTICOKE
EIGHT HOUR DISPERSION
FEB. 19, 1970 TO MAR. 11, 1970
SCALE: 1/2 1/4 0 1 MILES
DRAWN BY: A.R.S.
DATE: JAN., 1969
CHECKED BY:
DRAWING Nº: 69-6-GL

FIG. 5

Table 3 compares the five hour dispersion coefficients for the ice and non-ice condition by direction. The higher coefficient values indicate better dispersion characteristics.

TABLE 3

COMPARISON MEAN FIVE HOUR TWO-DIMENSIONAL DISPERSION COEFFICIENTS (cm^2/sec)

Direction (going to)	Dec. 22, 1969 Jan. 27, 1970	Feb. 19 to Mar. 11, 1970	Oct. 1968	May 1969
North	1.92×10^5	0	0.47×10^5	0.84×10^5
East	4.38×10^5	1.19×10^5	2.58×10^5	2.18×10^5
South	2.04×10^5	0.84×10^5	1.03×10^5	1.19×10^5
West	4.82×10^5	1.29×10^5	2.72×10^5	1.95×10^5

DISCUSSION

The mean characteristics of water movement for December 22, 1969 to January 27, 1970 (referred to as January), and the results for October 1968 have similar maximum velocities and resultants in both direction and magnitude. The results for the period February 19 to March 11, 1970 (referred to as February) have much lower maximum velocities and very long periods of no water movement. The resultant current for February is significantly less than January and in the

opposite direction to January. This reflects the longer period of zero velocity in February which is almost twice as long as January's period of zero velocity. Longer periods of no water movement and higher persistence factors occurred in both January and February than in October 1968. If the records of currents are examined, periods of velocity jetting appear when current magnitudes build-up over some hours then decreases to zero again, particularly in January. This build-up did not occur at any fixed time period during the operation of the meter. Measured temperature variations (Table 3, Apx. 1, page 3) affirm the jetting of current occurring in January. January temperatures vary from $0^{\circ}C$ to greater than $2^{\circ}C$, whereas February temperatures vary from $0^{\circ}C$ to $0.8^{\circ}C$. Whether temperature is a cause or result of the current jetting is not known. If the under ice conditions are similar to the ice free conditions, the temperature effects are probably transported by the currents.

The mean monthly dispersion in January and February 1970 are poorer than September and October 1968. A direction reversal occurred between the January and February periods for the mean monthly dispersion characteristics. On a five hour basis, February's dispersion is extremely poor compared to both January 1970, October 1968, and May 1969, whereas January's five hourly dispersion is

greater than October 1968 and May 1969, due to the short period jetting occurring in the record.

CONCLUSIONS

Winter currents under the ice cover at Nanticoke differ from currents occurring in the ice free months. Currents under the ice are generally smaller with longer periods of zero velocity than those occurring in the ice free months. Velocity jetting occurred under the ice when currents increased from nearly zero to 14 to 25 cm/sec, then reduced to zero again in a period of a day. Both the monthly mean and hourly dispersion under ice are significantly smaller than the ice free condition. In February, dispersion was extremely small and one would expect some accumulation to occur in the area in this period.

The temperatures occurring immediately after an ice cover vary between 0 to 2°C, although they remain close to zero for 75 percent of the time. After the ice cover has had time to stabilize, the temperature variation reduces to 0 to 0.8°C.

RECOMMENDATIONS

This study was undertaken to determine what effects the winter ice cover would have on the water intake. The poorer dispersion characteristics coupled with the long periods of little or no water

movement in the area indicate that waste discharges in geographical proximity of the intake should be avoided. The distance from the intake is obviously dependent upon the size and quality of the discharge as allowances must be made for accumulations occurring over periods of 7 days when little or no water movement occurred. Waste discharges of 0.56 m^3/sec (20 cfs) should be kept 4 to 6 kms to either side of the intake, (preferrably to the east) as a rough guide.

There would also be some advantage in altering the intake so that it draws water from a larger area. However, this is not practical as the water intake is a large fixed structure primarily designed to serve the cooling water needs of the Nanticoke thermal electric generating station.

REFERENCES

1. PALMER, M.D., 1968. "Currents in the Nanticoke Region of Lake Erie". Ontario Water Resources Commission, 135 St. Clair Ave. W., Toronto 195, Ontario.

2. PALMER, M.D., and IZATT, J.B., 1969. "Great Lakes Near-Shore Modelling from Current Meter Data. Ontario Water Resources Commission, 135 St. Clair Ave. W., Toronto 195, Ontario.

TABLE I

DATE: 22 DEC. 1969 TO 27 JAN. 1970

FREQUENCY TABLE - METER 021

SPEED (CM/SEC.)	DIRECTION COMING FROM (DEGREES) 337.50 - 22.49	22.50 - 67.49	67.50 - 112.49	112.50 - 157.49	157.50 - 202.49	202.50 - 247.49	247.50 - 292.49	292.50 - 337.49	ROW SUMS
0.00 - 0.30	0.792	1.642	9.397	4.473	1.358	8.350	13.218	1.217	40.447
0.31 - 2.99	0.000	0.510	5.095	1.048	0.396	3.510	3.557	0.141	14.257
3.00 - 5.99	0.000	0.934	8.463	0.567	0.085	3.877	5.973	0.000	19.899
6.00 - 8.99	0.000	0.538	1.869	1.048	0.000	2.095	6.878	0.000	12.428
9.00 - 11.99	0.000	0.085	0.227	0.311	0.000	0.085	2.519	0.000	3.227
12.00 - 14.99	0.000	0.000	0.141	0.114	0.000	0.000	2.831	0.000	3.086
15.00 - 17.99	0.000	0.000	0.057	0.000	0.000	0.000	1.359	0.000	1.416
18.00 - 20.99	0.000	0.000	0.028	0.000	0.000	0.000	1.302	0.000	1.330
21.00 - 29.99	0.000	0.000	0.000	0.000	0.000	0.000	2.775	0.000	2.775
COLUMN SUMS	0.792	3.709	25.277	7.561	1.839	17.917	40.412	1.358	988.650

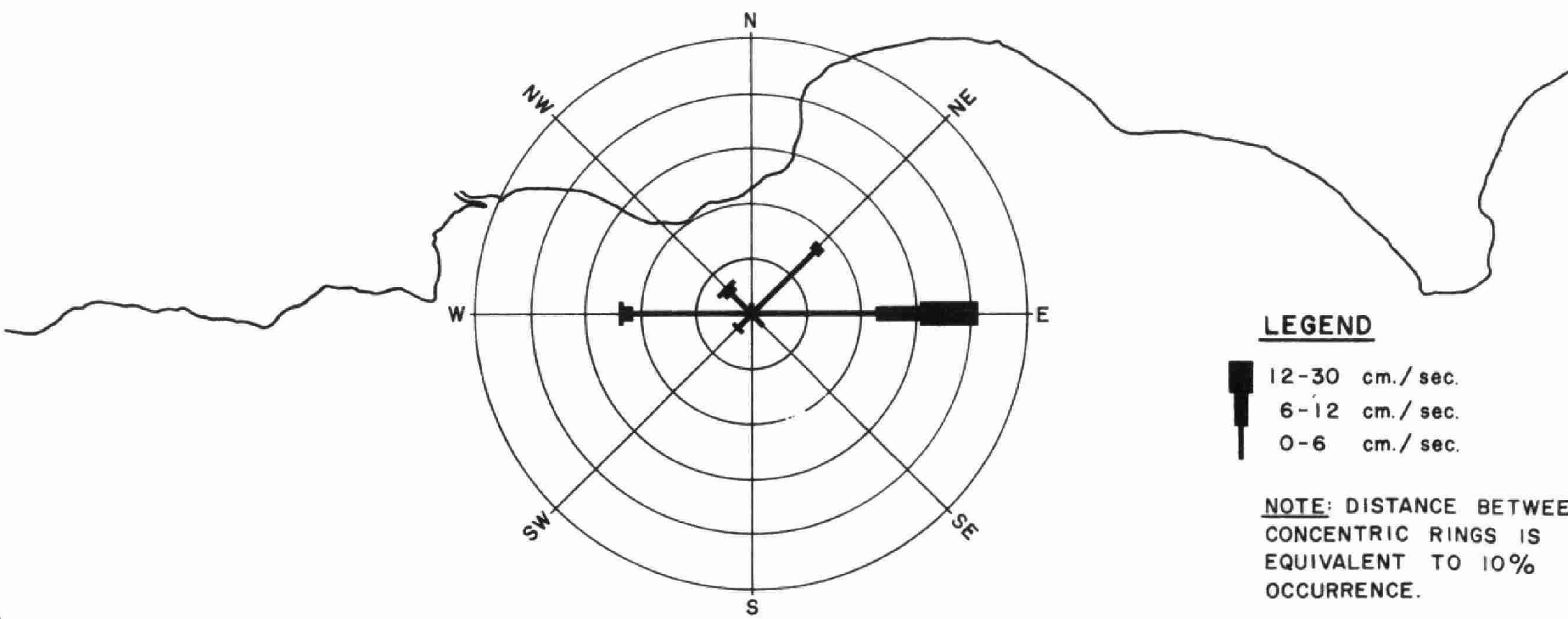
RESULTANT CURRENT IS 2.163 CM/SEC. AT 254.609 DEGREES

MEAN CURRENT IS 3.83 CM/SEC.

PERSISTENCE IS 0.56

TOTAL No. READINGS 3533

MAXIMUM CURRENT IS 28.24 CM/SEC.



LEGEND

12-30 cm./sec.
6-12 cm./sec.
0-6 cm./sec.

NOTE: DISTANCE BETWEEN CONCENTRIC RINGS IS EQUIVALENT TO 10% OCCURRENCE.

SCALE:

CURRENT TRANSPORT ROSE

TABLE 2

DATE: 19 FEB. TO 11 MAR. 1970

FREQUENCY TABLE - METER 021

SPEED (CM/SEC.)	DIRECTION COMING FROM (DEGREES) 337.50 - 22.49	22.50 - 67.49	67.50 - 112.49	112.50 - 157.49	157.50 - 202.49	202.50 - 247.49	247.50 - 292.49	292.50 337.49	ROW SUMS
0.00 - 0.30	1.02	3.92	43.26	2.29	0.18	0.51	16.53	5.85	73.64
0.31 - 2.99	0.04	0.00	2.61	0.04	0.00	0.00	2.72	0.15	5.55
3.00 - 5.99	0.00	0.00	7.36	0.04	0.00	0.00	1.99	0.15	9.54
6.00 - 8.99	0.00	0.04	4.86	0.00	0.00	0.00	0.98	0.00	5.87
9.00 - 11.99	0.00	0.00	2.76	0.00	0.00	0.00	1.16	0.00	3.92
12.00 - 14.99	0.00	0.00	1.27	0.00	0.00	0.00	0.18	0.00	1.45
15.00 - 17.99	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04
COLUMN SUMS	1.05	3.95	62.15	2.36	0.18	0.51	23.57	6.24	100.00

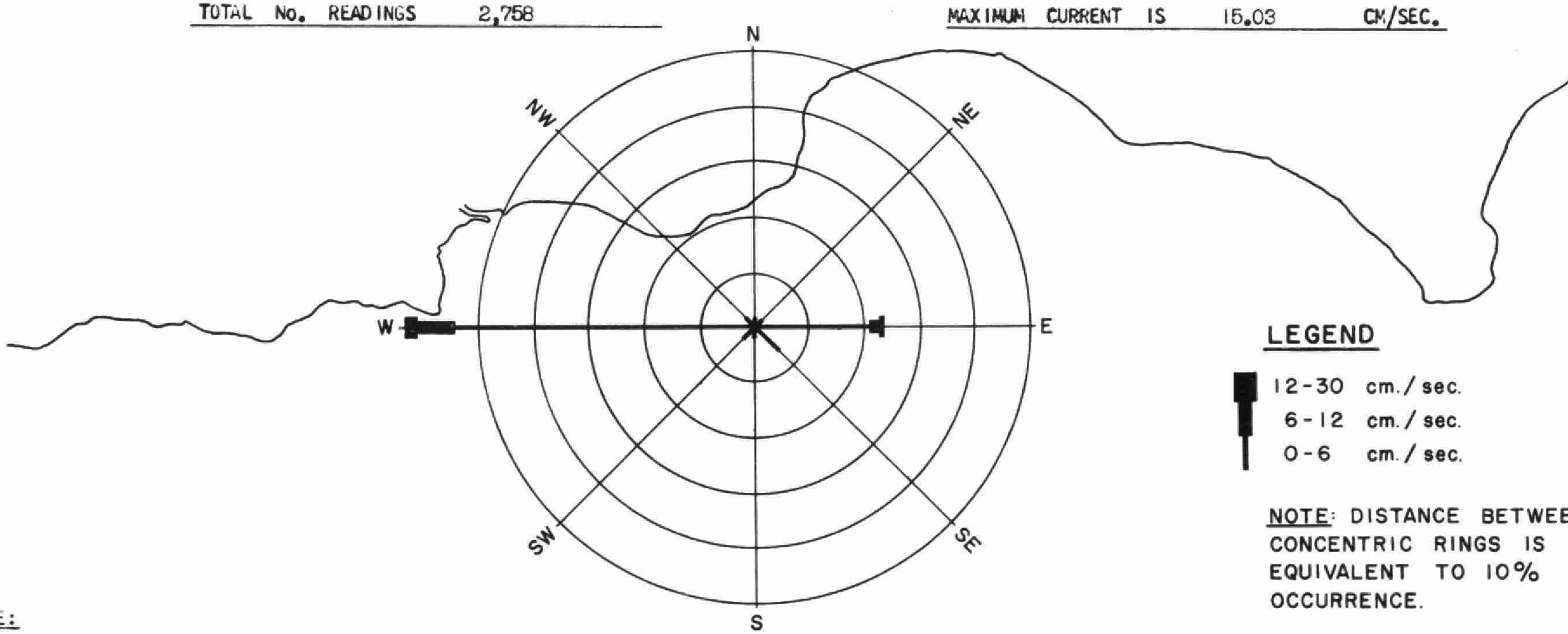
RESULTANT CURRENT IS 0.91 CM/SEC.AT 69.10 DEGREES

MEAN CURRENT IS 1.50 CM/SEC.

PERSISTENCE IS 0.61

TOTAL No. READINGS 2,758

MAXIMUM CURRENT IS 15.03 CM/SEC.



CURRENT TRANSPORT ROSE

LEGEND

12-30 cm./sec.
6-12 cm./sec.
0-6 cm./sec.

NOTE: DISTANCE BETWEEN CONCENTRIC RINGS IS EQUIVALENT TO 10% OCCURRENCE.

SCALE:

TABLE 3

TEMPERATURE FREQUENCY

TEMPERATURE °C	FREQUENCY AS PERCENT Dec. 22, 1969 to Jan. 27, 1970	Feb. 19 to March 11, 1970
0.0 - 0.19	75.13	9.77
0.20 - 0.39	6.00	24.09
0.40 - 0.59	6.01	40.91
0.60 - 0.79	2.40	25.00
0.80 - 0.99	2.92	
1.00 - 1.49	3.26	
1.50 - 1.99	4.12	
2.0 - 10.0	.17	
	100.00	100.00

APPENDIX 2

METER 021 LOG

Location: $80^{o}02'43'W$, $42^{o}47'24'N$

Depth of Water: 31 St. (meter 22 St. below surface)

Meter Details:

DATE	SERIAL #159 TIME IN	OUT	DECIMAL SERVICE
Dec. 22/69	1140		Meter installed and started drogue tracking.
Jan. 15/70			Hydrophone monitor but no signal received - checked by driver - meter functioning.
Jan. 27/70		1240	Meter #159 replaced by #164 hydrophone monitor - no signal.
Feb. 19/70	1244		Meter #164 replaced by #159 hydrophone monitor - meter functioning.
March 11/70		1220	Meter #159 replaced by #144.
	1330		Meter #144 replaced by #159 as #144 failed to operate. Dessicators, tape, "O" ring, and batteries replaced in #159 before reinstalling.
April 22/70		0850	Meter removed - still operating.
April 29/70			Bearings changed.
April 30/70			Calibration tests carried out.

Meter Details:

DATE	SERIAL #164 TIME IN	OUT	DECIMAL #261 SERVICE
Dec. 21/69			Position and tension of star-wheel adjusted, and tension on the pinch wheel assembly also adjusted. Replaced bearings, batteries, and tape.
Jan. 27/70	1240		Meter #159 replaced by #164. Hydrophone monitor received no signal - hydrophone later proved to be faulty.
Feb. 19/70		1240	Meter #164 replaced by #159. #164 had no record - due to faulty clock. Cleaned clock contacts.

APPENDIX 3

TOW TANK CALIBRATIONS

Description of Tank

The tow tank at the Hydro-Electric Power Commission's hydraulic model laboratory in Toronto was used. The tank is 61 cms wide, 30 cm deep, and 15.2m long with a test section 12.2 m long. A travelling carriage cable driven by a constant speed electric motor through manually adjustable gear reduction drives provided numerous carriage speeds in the 3 to 30 cm/sec range. In all cases, carriage speed was determined with a stop watch during a run.

Velocity Calibration

The meter was secured to the movable carriage and aligned properly along the tank. Successive runs were made down the tank at each speed until a reasonable binary number change occurred in the meter. The number of runs is dependant on the speed. At speeds in excess of 18 to 20 cm/sec, a bow wave and wake were observed in the tank due to the accelerated flow around the meter. The current meter diameter is approximately 15 cm, which is half the depth.

Calibration 30, April 1970

Meter #159, Decimal #240

Plessey M021

Carriage Velocity cm/sec	Meter Velocity cm/sec
3.67	2.28
4.89	4.04
9.75	10.08
19.35	24.19
29.03	44.36

It will be observed that in the table of readings that the difference between the meter and carriage velocities increases nonlinearly as the carriage velocity increases. This trend is typical of accelerated flows about obstacles. After tow tank tests, the meter was checked employing a non-calibrated fan and found to respond linearly over a large velocity range. The blockage is not really a problem as the main area of interest is less than 15 cm/sec.

Temperature

The thermistor of the current meter was checked against a thermometer accurate to $\pm$ 0.05^{o}C.

Calibration 30, April 1970

Meter #159, Decimal #240

Plessey M021

Thermometer °C	Meter °C
21.7	22.0

DATE DUE